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STATPLOT STATISTICAL PLOTTING PROGRAM

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OCCUPATIONAL AND ENVIRONMENTAL
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Brooks AFB TX 78235-5000

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Base bioenvironmental engineering (BEE) shops perform statistical analysis on industrial hygiene and environmental sample results by calculating the mean, standard deviation and 95% confidence intervals. However, these calculations assume the sample data follows a normal (Gaussian) distribution. Data should be analyzed for the distribution to be sure the proper statistics are being used. This technical report describes the microcomputer program "STATPLOT" written in BASIC, which plots sample results on linear vs. probability axes and on logarithmic vs. probability axes. Sample results which follow a normal (Gaussian) distribution will appear as a straight line on the linear vs. probability plot. Sample results which are log normal will appear as a straight line on the logarithmic vs. probability plot. STATPLOT is provided for use by all BEE shops in reviewing the statistical distribution of sample data (univariate analysis).

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STATPLOT STATISTICAL PLOTTING PROGRAM

INTRODUCTION

Purpose

This technical report describes the microcomputer program "STATPLOT" written in an IBM compatible BASIC which plots sample results on linear vs. probability axes and on logarithmic vs. probability axes. Sample results which follow a "normal" (Gaussian) distribution will appear as a straight line on the linear vs. probability plot. Sample results which are "log normal" will appear as a straight line on the logarithmic vs. probability plot.

Problem

Base Bioenvironmental Engineering (BEE) shops perform statistical analysis on industrial hygiene and environmental sample results by calculating the mean, standard deviation, and 95% confidence intervals. However, these calculations assume the data follows a normal (Gaussian) distribution. Past studies have shown industrial hygiene air sampling data is log normally distributed (1). No studies have proven the distribution for noise, radiation or environmental sampling (2). Data should be analyzed for a normal distribution to be sure the proper statistics are being used. While microcomputer statistical programs are widely available (SAS, SPSS, SYSTAT, MINITAB), they are not generally purchased or used by base level BEE offices.

Scope

STATPLOT is provided for use by all BEE shops in reviewing the statistical distribution of sampling data (univariate analysis). A full discussion of statistical data analysis is beyond the scope of this report and is not provided. Texts and night classes in statistics are widely available and recommended.

DISCUSSION

Theory of Operation

The BASIC program STATPLOT reads sample values from an ASCII text file, with one sample value per line of text. The values are sorted in decreasing order and printed out on a 80-column printer to show the operator the values used for its analysis (Appendix A). Starting on a new page, STATPLOT prints a one-page plot with linear vs. cumulative probability axes. The data points are plotted as '0's, and a straight line which shows how the data would be plotted if it followed a normal distribution is plotted as a series of '/'s. A summary of sample statistics which assume the data is normally distributed is printed at the bottom of the plot. STATPLOT then takes the logarithm (base

ten) of all data points and prints a second plot and statistical analysis assuming the data is log normally distributed.

Using STATPLOT

Place data to be analyzed into a file as ASCII text with one data point per line. This can be done directly from MSDOS EDLIN, by converting a word processor text file to ASCII (usually as a utility or option on most word processing programs), or by printing the data from a spreadsheet directly to a file instead of the printer.

Copy STATPLOT into the same directory as the BASIC you use (TURBO BASIC, BASICA, GWBASIC).

Start your BASIC program. Type the commands <LOAD "STATPLOT"> and then <RUN>.

Turn on the printer connected to the computer and position the paper to the top of a page.

Answer the program prompt with the name of the file containing the data to be analyzed and the desired title to describe the plots.

Wait for the program to sort and plot the data. Three pages will be printed for each data set analyzed.

Interpreting Plots

Best Fit: Comparing plotted data to a straight line for the normal and log normal plots indicates which distribution the data follows. Appendix A shows real noise dosimetry data for Dover AFB forklift operators plotted on normal and log normal plots. While the data appears to better fit a normal plot, either plot could be used. Note that this log normal plot lists a Geometric Standard Deviation (GSD) of 1.08. This is well below the typical GSD of 1.5 to 2.0 for chemical exposures (3). (The GSD is a measure of the variability of data for a log normal distribution, in the same way the standard deviation describes variability for a normal distribution.) For such low GSDs, data appears to fit normal and log normal plots equally well. Appendix B shows normal (Gaussian) distributed data plotted on normal and log normal plots. Note that the normally distributed data appears curved on a log normal plot. Appendix C shows log normal distributed data plotted on normal and log normal plots. Log normally distributed data also appears curved on a normal plot.

Bimodal Distributions: A data set sometimes includes sample results from two groups of data, each with their own mean and standard deviation (or geometric mean and GSD). This can occur because the surveyor does not recognize the different job tasks or potentials for exposure. (Example: Noise exposures for tool crib operators vs. engine mechanics.) This will appear on a normal or log normal plot as an S-shaped curve or curve with two straight ends connected by a rounded elbow. The two underlying distributions can be estimated (with an active imagination, a straight ruler and a sharp pencil) as

the asymptotes of the ends of the curve. Appendix D shows a bimodal normal distribution as plotted with STATPLOT.

Confidence Intervals: Means and confidence intervals for the data can be read directly from the desired plot. The mean is read by finding the point on the graph aligned with the position for 50% probability. The upper 95% confidence limit is read at the 95% probability position.

Number of Samples: Trying to perform statistical analysis on one sample result will cause STATPLOT to abort. Analyzing only two sample results will give what appears to be a perfect fit of the data to both normal and log normal distributions. However, this is only a demonstration of the rule of geometry where any two points define a straight line, and should not be interpreted as having collected reliable data. As the number of samples approaches 10 or 15 samples, the ability to view the underlying statistical distribution improves.

RECOMMENDATION

Use STATPLOT to plot sampling data before making assumptions about the statistical distribution or calculating 95% confidence intervals.

REFERENCES

1. Leidel, N.A., K.A. Busch and W.E. Crouse, Exposure Measurement, Action Level and Occupational Environmental Variability. National Instititue of Occupational Safety and Health (NIOSH), DHEW (NIOSH) Pub. No. 76-131 (1975)

2. Leidel, N.A., K.A. Busch and J.R. Lynch, Occupational Exposure Sampling Strategy Manual. National Instititue of Occupational Safety and Health (NIOSH), DHEW (NIOSH) Pub. No. 77-173 (1977)

3. American Conference of Governmental Industrial Hygienists, Inc. (ACGIH), Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinatti OH, 1990-1991 ed., (1990)

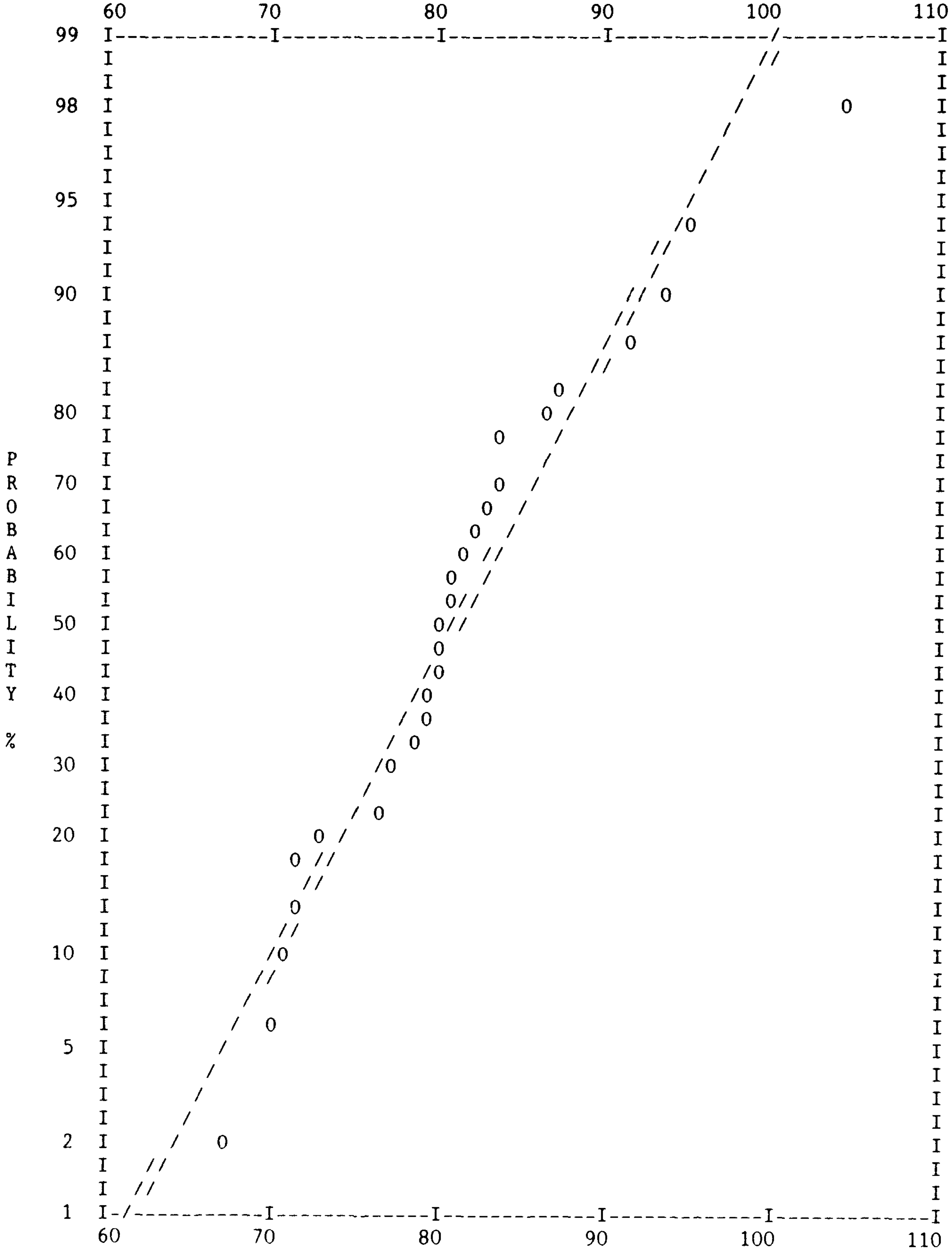
APPENDIX A

Sample STATPLOT Output of Noise Dosimetry Data

SAMPLE PRINTOUT

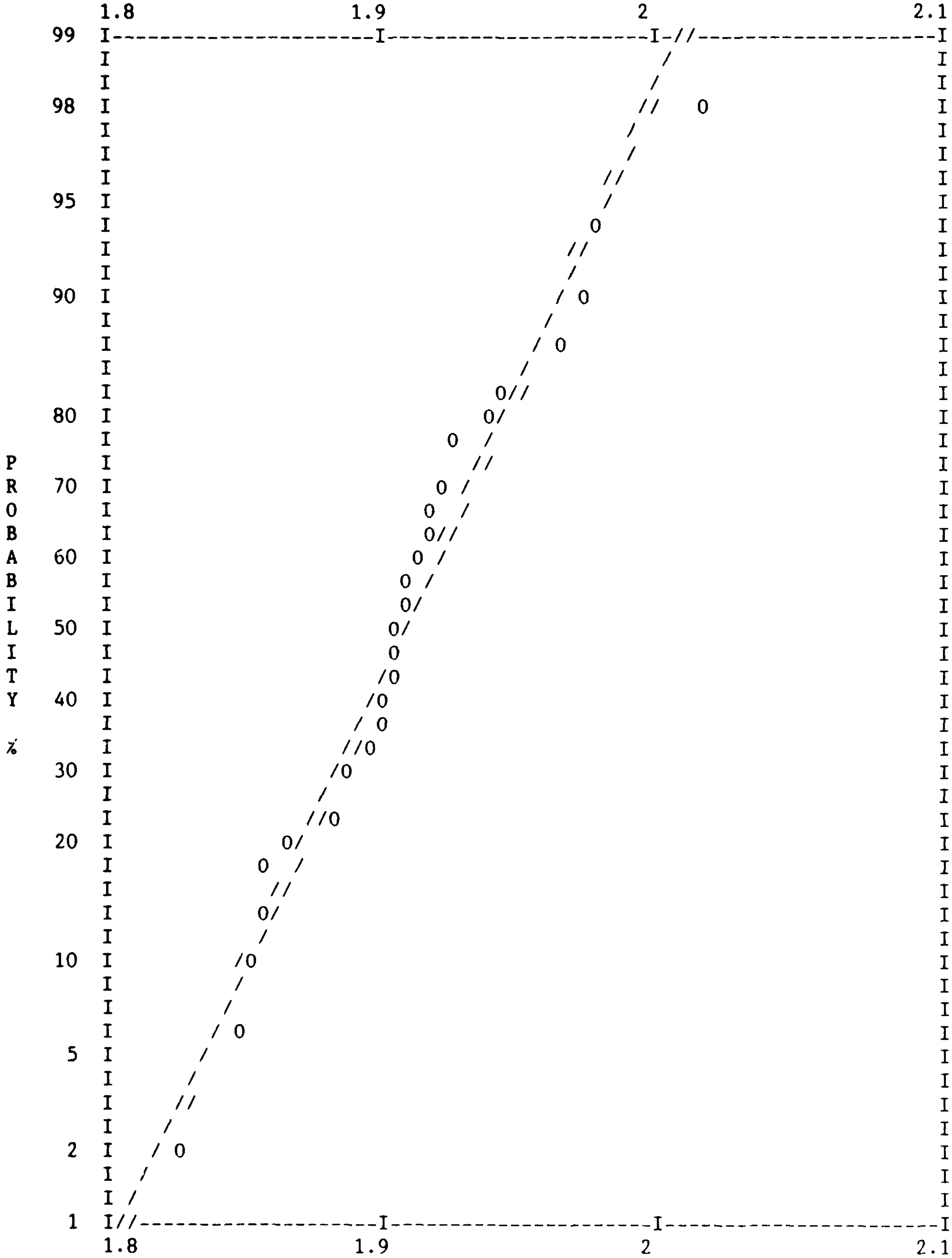
```
 Data points from file: b:forklift.dat
 67.3
 70.4
 71.2
 72
 72.1
 73.2
 76.8
 77.5
 78.7
 79.5
 79.6
 80.3
 80.6
 80.7
 80.8
 81.2
 81.7
 82.4
 82.9
 83.9
 84.2
 86.8
 87.4
 92.1
 93.7
 95.1
 104.3
Data in DESCENDING order is:
 104.3
 95.1
 93.7
 92.1
 87.4
 86.8
 84.2
 83.9
 82.9
 82.4
 81.7
 81.2
 80.8
 80.7
 80.6
 80.3
 79.6
 79.5
 78.7
 77.5
 76.8
 73.2
 72.1
 72
 71.2
 70.4
 67.3
```

LINEAR vs. CUMULATIVE PROBABILITY
Forklift Operator Noise Dosimetry



'//' = normal (Gaussian) distribution based on the statistics of the data
Mean = 81.34815 Std.Dev = 8.27319
'0' = data points

LOG (base 10) of DATA POINTS vs. CUMULATIVE PROBABILITY
Forklift Operator Noise Dosimetry



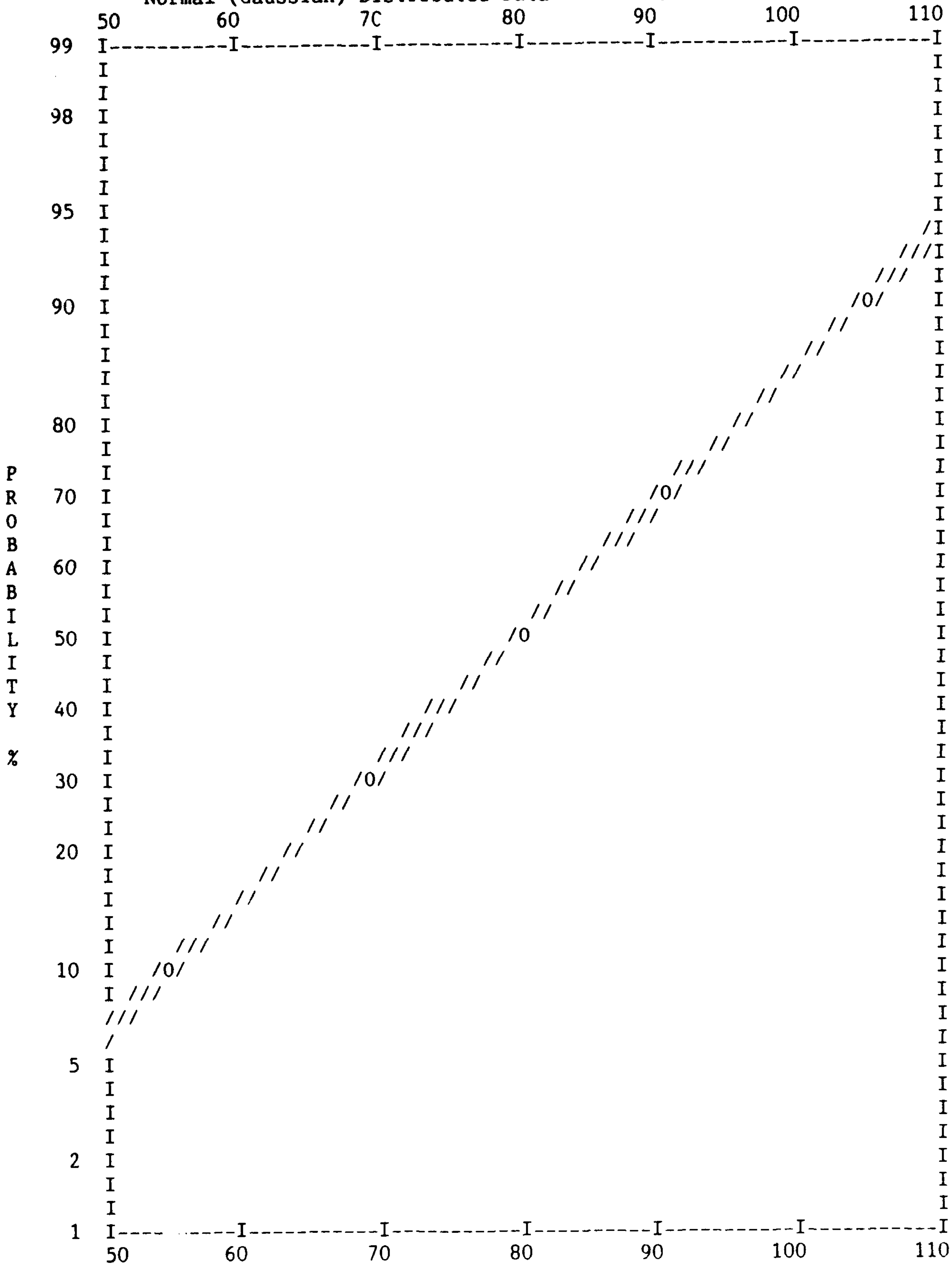
'/' = Log-Normal distribution based on the statistics of the LOGed data
Geometric Mean = 10^ 1.908257 = 80.95736
Geometric Std.Dev (GSD) = 10^ 4.311791E-02 = 1.104379
'0' = LOGed (base 10) data points

APPENDIX B

Plot of Normal (Gaussian) Data

LINEAR vs. CUMULATIVE PROBABILITY

Normal (Gaussian) Distributed Data   Mean 80   Std Dev 20



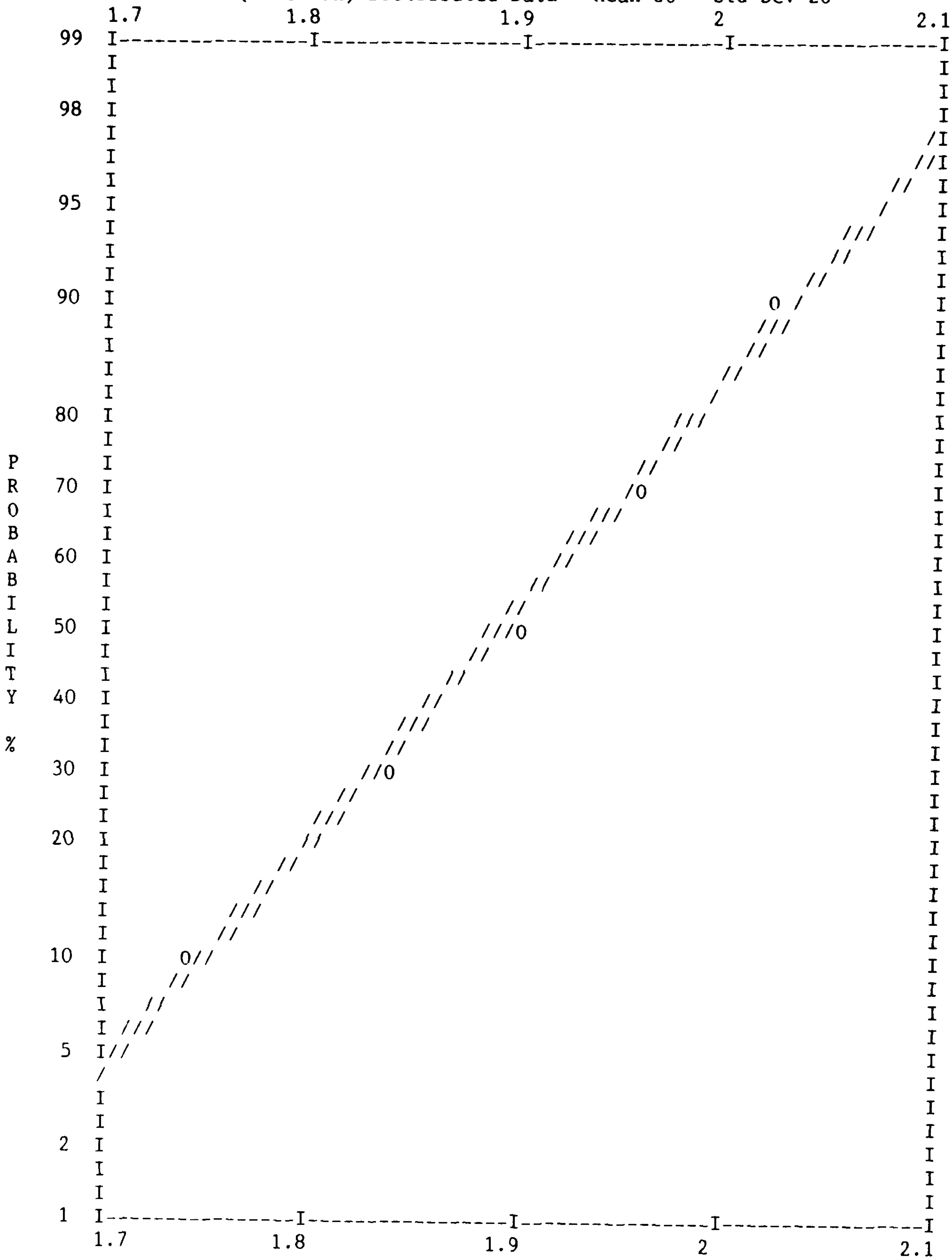
'/' = normal (Gaussian) distribution based on the statistics of the data

Mean = 80   Std.Dev = 19.31321

'0' = data points

LOG (base 10) of DATA POINTS vs. CUMULATIVE PROBABILITY

Normal (Gaussian) Distributed Data   Mean 80   Std Dev 20



'//' = Log-Normal distribution based on the statistics of the LOGed data

Geometric Mean = 10^ 1.892507 = 78.07403

Geometric Std.Dev (GSD) = 10^ .1085414 = 1.28393

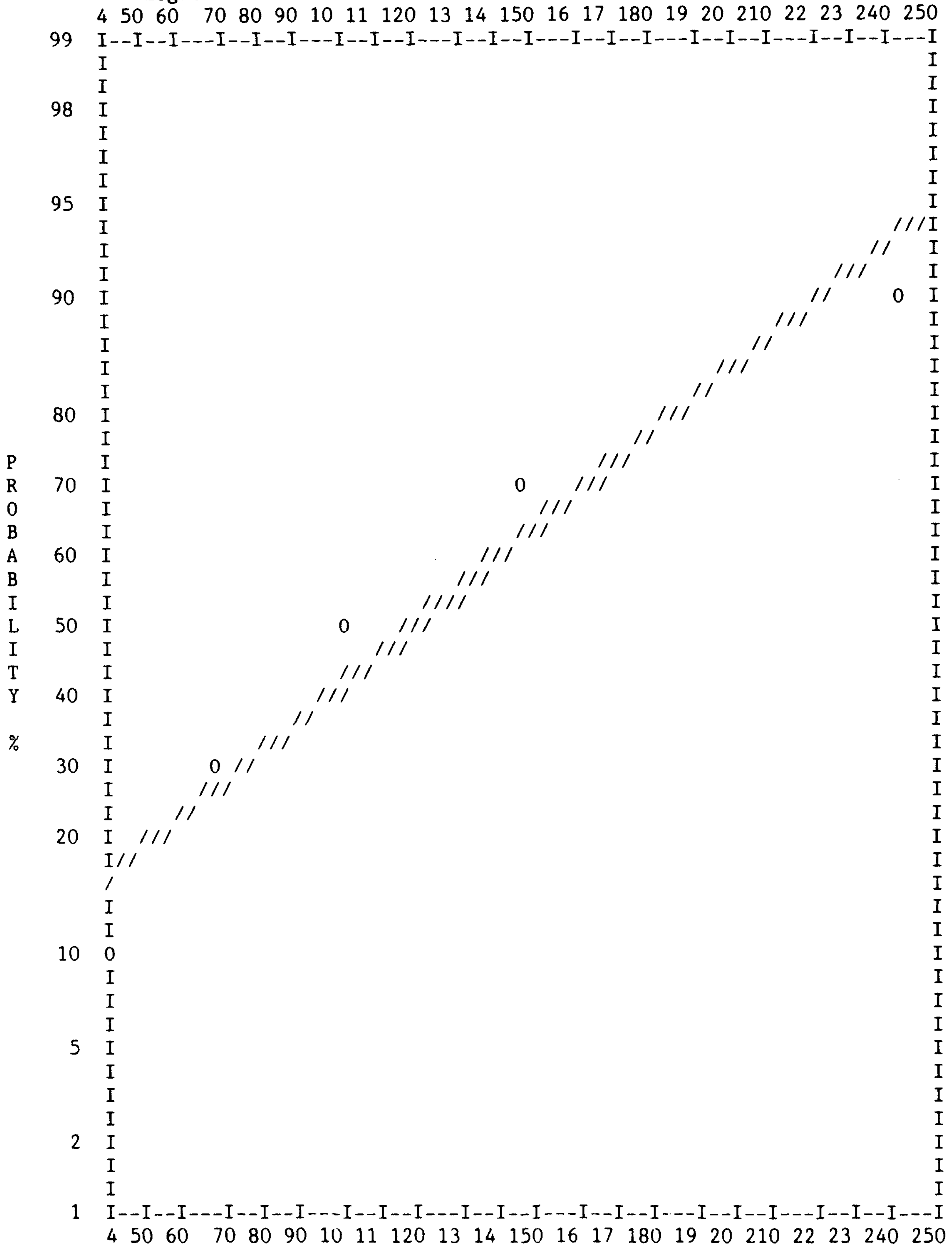
'0' = LOGed (base 10) data points

APPENDIX C

Plot of Lognormal Data

LINEAR vs. CUMULATIVE PROBABILITY

Lognormal Distributed Data   Geometric Mean 100   GSD 2

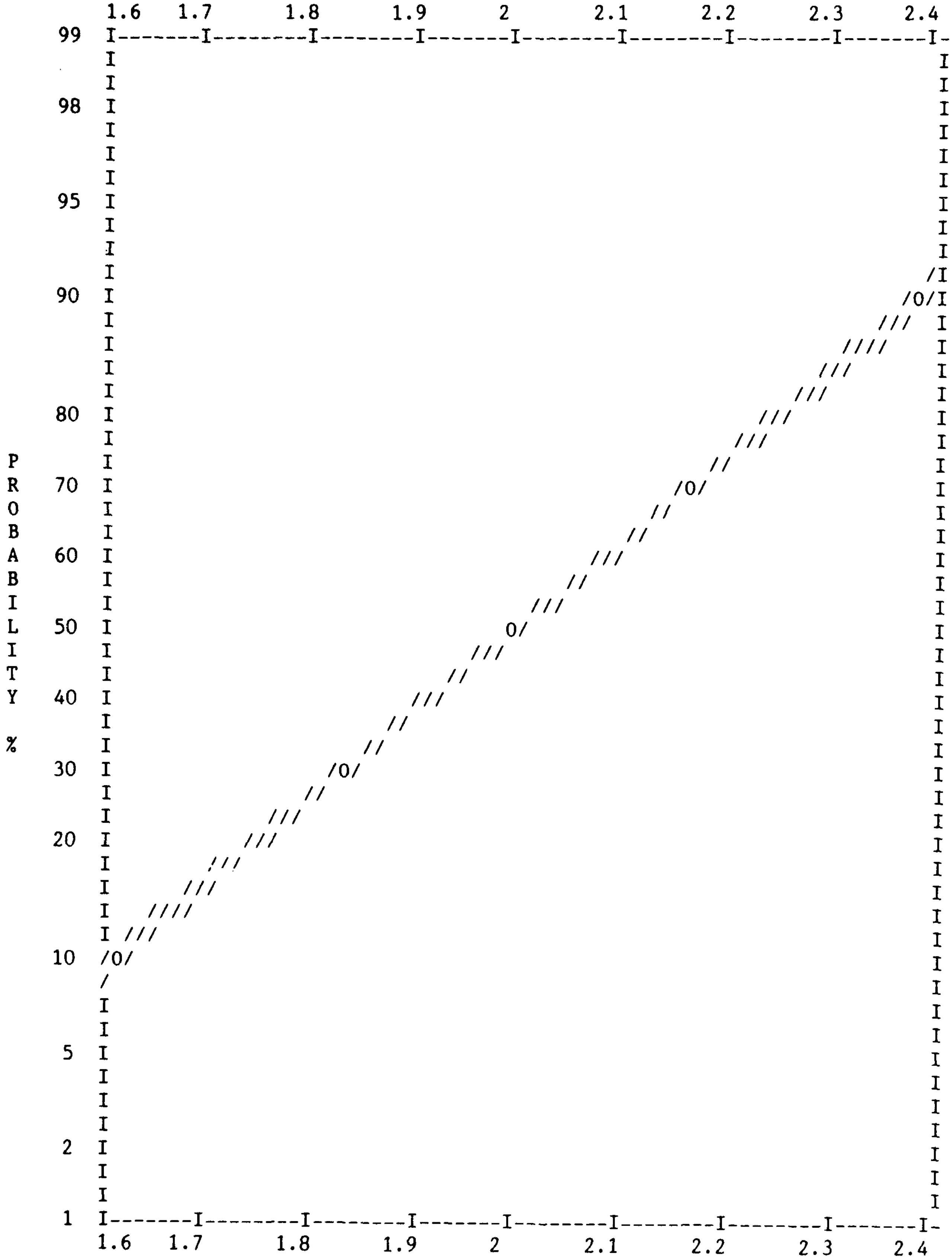


'/' = normal (Gaussian) distribution based on the statistics of the data
Mean = 119.6   Std.Dev = 79.04935

'0' = data points

LOG (base 10) of DATA POINTS vs. CUMULATIVE PROBABILITY

Lognormal Distributed Data   Geometric Mean 100   GSD 2



'/' = Log-Normal distribution based on the statistics of the LOGed data

Geometric Mean = 10^ 1.999721 = 99.93582

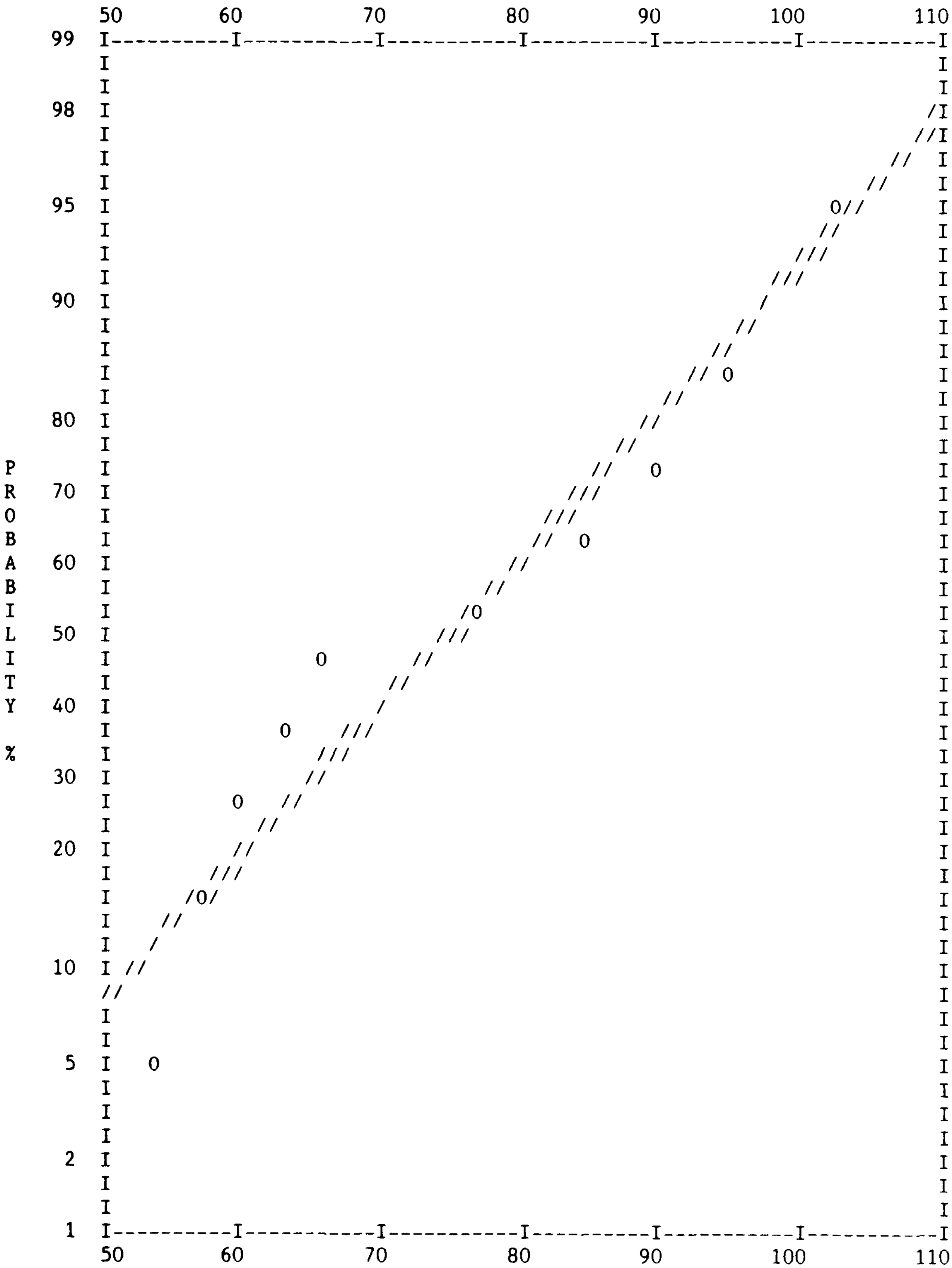
Geometric Std.Dev (GSD) = 10^ .2960732 = 1.977303

'0' = LOGed (base 10) data points

APPENDIX D

Plot of Bimodal Distribution

LINEAR vs. CUMULATIVE PROBABILITY
Bimodal Distribution with Means at 60 and 90



'/' = normal (Gaussian) distribution based on the statistics of the data
Mean = 75 Std.Dev = 17.41009
'0' = data points

APPENDIX E

STATPLOT Program Listing

```
10   ' STATPLOT program to graphically print sampling results on
20   ' LINEAR vs PROBABILITY axes for a normal (Gaussian) distribution, and
30   ' LOG vs PROBABILITY axes for a log normal frequency distribution.
40   'Written by Maj John Seibert, AL/OEMI, Industrial Hygiene Branch, 4 Jan 91
50   'Please send any suggested changes to AL/OEMI, Brooks AFB TX 78235
60   ' DSN 240-3214
70   'File FORKLIFT included on this disk as a sample input data file
80   '
90   DIM A(500)                'A() contains the data points
100   DIM L$(51),YSCALE$(51)   'L$ contains plot lines, YSCALE$ is y-axis
110                            '  probability labels
120   '
130   'Read in Data from disk file
140   '
150   CLS :PRINT :PRINT
160  PRINT "                      Be sure the printer is on and ON LINE" :PRINT :PRINT
170   PRINT "                       Data points should be ready in a disk file,"
180  PRINT "                             one data point per line." :PRINT :PRINT
190  PRINT "                        Negative and zero values will be ignored.":PRINT
200  INPUT "                              File name of data to be plotted";REC$
210  PRINT:INPUT"    Title of data to use as X-axis label";TITLE$
220  OPEN "I",#1,REC$
230  NPTS = 1
240    INPUT #1, A(NPTS)
250    IF EOF(1) THEN 290
260    IF A(NPTS) <= 0 THEN 240   'Throw out zero and negative values
270    NPTS = NPTS + 1
280  GOTO 240
290  CLOSE
300  '
310  'Print data points read in from file
320  '
330  LPRINT :LPRINT"  Data points from file: ";REC$ :LPRINT
340  FOR I = 1 TO NPTS
350    LPRINT A(I),
360  NEXT I
370  '
380  ' Sort data points in descending order to get ready for
390  ' cumulative probability distribution plotting
400  '
410  I = 1
420  IF I = NPTS GOTO 500
430    IF A(I) >= A(I+1) GOTO 480      'Consecutive values in correct order
440    SMALLER = A(I)
450    A(I) = A(I+1)
460    A(I+1) = SMALLER
470  GOTO 410
480    I = I + 1
490  GOTO 420
500  '
510  LPRINT:LPRINT"Data in DESCENDING order is: "
520  FOR I = 1 TO NPTS
530    LPRINT A(I),
540  NEXT I
```

```
550  LPRINT:LPRINT
560  '
570  'Prepare probability labels for Y axis
580  '
590  FOR I = 1 TO 51
600    YSCALE$(I) = SPACE$(6)     'First fill each label with 6 blanks
610  NEXT I
620  YSCALE$(1)="     1":YSCALE$(4)="     2":YSCALE$(8)="     5"
630  YSCALE$(12)="    10":YSCALE$(17)="    20":YSCALE$(20)="    30"
640  YSCALE$(23)="Y   40":YSCALE$(26)="L   50":YSCALE$(29)="A   60"
650  YSCALE$(32)="R   70":YSCALE$(35)="    80":YSCALE$(40)="    90"
660  YSCALE$(44)="    95":YSCALE$(48)="    98" :YSCALE$(51)="    99"
670  YSCALE$(33)="P     ":YSCALE$(31)="O     ":YSCALE$(30)="B     "
680  YSCALE$(28)="B     ":YSCALE$(27)="I     ":YSCALE$(25)="I     "
690  YSCALE$(24)="T     ":YSCALE$(21)="%     "
700  '
710  'Start with NORMAL (Gaussian) plot
720  '
730  LPRINT CHR$(12)                          'Page feed
740  LPRINT "                    LINEAR vs. CUMULATIVE PROBABILITY"
750  GOSUB 1050    'GOSUB CALC_POS to plot axis and data positions
760                'and print the body of the plot
770  '
780  'Print a footnote to the Plot
790  LPRINT "  '/' = normal (Gaussian) distribution based on the ";
800  LPRINT "statistics of the data"
810  LPRINT "          Mean = ";MEAN;"     Std.Dev = ";STDDEV
820  LPRINT "  'O' = data points
830 '
840 '  LOG-NORMAL plot
850 '
860  'Take log base 10 of all data points, and
865  ' use the CALC_POS subroutine again
870  '
880  FOR I = 1 TO NPTS
890    A(I) = LOG(A(I))/LOG(10)   'LOG function is base e. This formula gives
900  NEXT I                       'the base 10 log.
910  LPRINT CHR$(12)                        'Page feed
920  LPRINT "          LOG (base 10) of DATA POINTS vs. CUMULATIVE PROBABILITY"
930  GOSUB 1050    'GOSUB CALC_POS to plot axis and data positions
940               'and print the body of the plot
950 '
960 'Print a footnote to the Plot
970  LPRINT "  '/' = Log-Normal distribution based on the";
980  LPRINT " statistics of the LOGed data"
990  LPRINT "          Geometric Mean = 10^";MEAN;" = ";10^MEAN
1000  LPRINT "          Geometric Std.Dev (GSD) = 10^";STDDEV;" = ";10^STDDEV
1010  LPRINT "  'O' = LOGed (base 10) data points"
1020  LPRINT CHR$(12)     'Page feed
1030  STOP
1040  '
1050  'Subroutine CALC_POS to calculate axis and data positions
1060  '
1070 '
```

```
1080 'Calculate Statistics
1090 '
1100 AMAX = A(1): AMIN = A(NPTS)    'Know min & max, since already sorted
1110 SUM = 0
1120 FOR I = 1 TO NPTS
1130   SUM = SUM + A(I)
1140 NEXT I
1150 MEAN = SUM/NPTS
1160 '
1170 DIFF = 0
1180 FOR I = 1 TO NPTS
1190   DIFF = DIFF + (A(I)-MEAN)^2
1200 NEXT I
1210 STDDEV = SQR(DIFF/(NPTS-1))
1220  '
1230  'Calculate x-axis scale min and max based on input data
1240  XINTERV = 10^(INT(LOG(AMAX)/LOG(10))-1)  'One factor of 10 below AMAX
1250  XMIN = XINTERV * INT(AMIN/XINTERV)             'Interval multiple below
1260  XMAX = XINTERV * INT((AMAX+XINTERV)/XINTERV)   'Interval multiple above
1270  '
1280  'Prepare plot lines L$(1) through L$(51) for data
1290  FOR I = 1 TO 51
1300    L$(I) = "I" + STRING$(69," ") + "I"     '71 print positions per line
1310  NEXT I
1320  L$(1) = STRING$(71,"-")    'L$(1) and L$(51) are x-axis at top and bottom.
1330                             '1st character is at zero position on y-axis.
1340                             '71st character is at full scale position.
1350  '
1360  SCALE$ = SPACE$(75)    'SCALE$ is labels for x-axis values.  It starts 2
1370                         'spaces left of XAXIS$ and goes 2 spaces past.
1380  FOR X = XMIN TO XMAX STEP XINTERV
1390    POSITION = INT(70*(X-XMIN)/(XMAX-XMIN)) + 1
1400    'Place the I's in L$(1) to give axis tick marks
1410    L$(1) = LEFT$(L$(1),POSITION-1) + "I" + RIGHT$(L$(1),71-POSITION)
1420  '
1430    'Place the x-axis values in SCALE$ to show value at each tick mark
1440    POSITION = POSITION - INT(LEN(STR$(X))/2)
1450    IF POSITION < 1 THEN POSITION = 1      'Keep the values on the page
1460    IF POSITION > 76-LEN(STR$(X)) THEN POSITION = 76-LEN(STR$(X))
1470    SCALE$ = LEFT$(SCALE$,POSITION-1) + STR$(X) + RIGHT$(SCALE$,76-POSITION-LEN(STR$(X)

1480  NEXT X
1490  L$(51) = L$(1)           'Copy bottom axis into top axis
1500  '
1510  'Plot positions for the straight-line normal distribution based on the
1520  'mean and std dev. of the data
1530  FOR X = XMIN TO XMAX STEP (XMAX-XMIN)/100
1540    Z = (X-MEAN)/STDDEV
1550    YPOS = INT(26.5 + 10.74444*Z)                 'Y plot position
1560    XPOS = INT(70*(X-XMIN)/(XMAX-XMIN)) + 1       'X plot position
1570   IF XPOS<1 OR XPOS>71 OR YPOS<1 OR YPOS>51 GOTO 1590  'Data pt.off plot
1580    L$(YPOS) = LEFT$(L$(YPOS),XPOS-1) + "/" + RIGHT$(L$(YPOS),71-XPOS)
1590  NEXT X
1600  '
1610  'Plot positions for the data points
```

```
1620  FOR I = 1 TO NPTS
1630    PROB = 1 - (I-.5)/NPTS        'Use NPTS+1 to plot all data points
1640    IF PROB <= .5 GOTO 1680        'Formulas only work for Prob(y) <= 0.5
1650      T = SQR(LOG(1/(1-PROB)^2))  'For Prob(y) > 0.5, use 1-Prob(y)
1660      PROBFLAG = -1
1670      GOTO 1700
1680    PROBFLAG = 1
1690    T = SQR(LOG(1/PROB^2))
1700    Z = T - ((2.515517+.802853*T+.010328*T^2)/(1+1.432788*T+.189269*T^2+.001308*T^3))
1710    Z = Z * PROBFLAG                    'Correct Y for Prob(y) > 0.5
1720   YPOS = INT(26.5 - 10.74444*Z)       'Calculate Y position on plot
1730   XPOS = INT(70*(A(I)-XMIN)/(XMAX-XMIN)) + 1
1740   IF XPOS<1 OR XPOS>71 OR YPOS<1 OR YPOS>51 GOTO 1760  'Data pt.off plot
1750   L$(YPOS) = LEFT$(L$(YPOS),XPOS-1) + "O" + RIGHT$(L$(YPOS),71-XPOS)
1760 NEXT I
1770 '
1780 'Print main body of the Plot
1790 '
1800  SCALE$ = SPACE$(7) + SCALE$        'Add 7 spaces to the front of SCALE$
1810  LPRINT SPACE$(40-LEN(TITLE$)/2) + TITLE$      'Print data title centered
1820  LPRINT LEFT$(SCALE$,80)    'Be sure to print only 80 characters of SCALE$
1830  FOR I = 51 TO 1 STEP -1  'Line #51 at top descending to line #1 at bottom
1840    LPRINT YSCALE$(I);"  ";L$(I)
1850  NEXT I
1860  LPRINT LEFT$(SCALE$,80)
1870  LPRINT
1880 RETURN
1890 '
1900 END
```

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